REMARKS

Reconsideration and allowance of the above referenced application are respectfully requested.

Claims 41-44 and 46 stand rejected under 35 USC 103 as allegedly being unpatentable over U.S. patent number 4,894,526 issued to Bethea. This contention has been obviated by the amendment of the claims herein. Specifically, claim 2 has been amended to recite that the well layers are formed of a material that causes that causes a bound energy state resonant with the well top. This is not taught or suggested by Bethea, specifically states that the excited state is below the top of the barriers which define the quantum well. Bethea applies an external field or bias to excite these electrons out of the quantum well into the continuum. In the presence of the external field. The carriers then travel through the triangular barrier and enter the quantum state for the carrier transport. This is, for example, shown in Bethea's figure 4, which shows the excited carriers tunneling through this triangular shaped portion into the continuum.

The problem is that not all of the excited electrons will traverse this barrier, and therefore this reduces the signal-to-noise ratio.

Claim 41 specifies the first excited state in resonance with the barrier top that is at the same place for same energy as the barrier top, which defines the quantum well. In this special bound-to-continuum excited state, the carriers do not nrrf to tunnel through a barrier. The carriers can easily drift into the continuum state with no tunneling. This increases the escape probability, and minimizes quantum mechanical reflections. This hence provides higher photo current and higher signal-to-noise ratio.

The rejection alleges that tunneling is known with thinner barriers. While true, it is respectfully suggested that the tunneling difficulty increases exponentially with the thickness of the barrier. The relatively thick barrier shown in Bethea would reduce the amount of carriers which escape. Therefore, the present system is completely patentable over Bethea who does not teach or suggest this feature. The dependent claims, that depend therefrom, should be allowable for similar reasons.

In item 8, claims 47-50 are rejected, however, the detailed remarks discuss other claims which or not specifically rejected, such as claims 77-78. Hence the rejection is not entirely understood. However, to the extent that the dependent claims are being rejected, it is respectfully suggested that the claims should be allowable for similar reasons to those of the

respective independent claims.

It is not clear whether that the other claims 71-83 were specifically rejected over prior art. In any case, the same arguments which have been provided above apply for these claims. Claim 71 has been amended to include the limitations of claim 74 therein. The amended claim specifies that the bound energy state is resonant with a top portion of the well, and therefore this claim should be allowable for reasons discussed above.

In view of the above amendment and remarks, therefore, all of the claims should be in condition for allowance. A formal notice to do that is respectfully solicited.

Please apply the $55.00 one month extension fee and any other charges or credits to Deposit Account No. 06-1050.

Respectfully submitted,

Date: 11/27/02

Scott C. Harris
Reg. No. 32,030

Fish & Richardson P.C.
Customer Number: 20985 * *
4350 La Jolla Village Drive, Suite 500
San Diego, California 92122
Telephone: (858) 678-5070
Facsimile: (858) 678-5099
10233487.doc

Attached is a marked-up version of the changes being made by the current amendment.

Attorney's Docket No.: 06816/035003/CIT 2426-C-C

Version with markings to show changes made

In the claims:

Please cancel claim 42 and 74.

Please amend the remaining claims as follows:

2. A method, comprising:

forming a plurality of quantum well elements, each element having a barrier layer and well layer with each well layer being formed between two barrier layers, each well layer having a well bottom, and a well top; and

supporting bound energy levels within each said well layer, with an excited bound energy level being at a level that is close to resonant with said well top.

3. A method as in claim 2, wherein said excited bound energy level is within 5 percent of an edge defining said well top.

4. A method as in claim 2, wherein said forming comprises forming said well layer from a first material and forming said barrier layer from a second material different from said first material.

5. A method as in claim 4, wherein said supporting comprises controlling properties and quantities of said first and second materials to support said bound energy level being close to resonant with said well top.

6. A method as in claim 4, wherein said first and second materials include GaAs, and $Al_xGa_{1-x}As$.

7. A method as in claim 6, further comprising controlling properties and quantities of said GaAs and said $Al_xGa_{1-x}As$ to obtain said bound energy level.

8. A method as in claim 6, further comprising increasing a well depth by increasing a thickness of GaAs, to increase a separation between a ground state and an excited state.

9. A method as in claim 6, wherein said GaAs well layers are 45 angstroms thick, and said $Al_xGa_{1-x}As$ barrier layers are 500 angstroms thick.

10. A method as in claim 9, wherein x, representing a mole fraction of Al in said $Al_xGa_{1-x}As$, is substantially 0.29.

11. A method as in claim 2, wherein said forming comprises forming a well layer of GaAs between barrier layers of $Al_xGa_{1-x}As$.

12. A method as in claim 11, further comprising an initial step of forming a semi insulating GaAs substrate, said forming comprising forming quantum well elements on said substrate.

13. A method as in claim 12, further comprising forming an electrical contact layer on said substrate.

14. A method as in claim 13, wherein said electrical contact layer is formed between said semi insulating substrate, and said plurality of quantum well elements.

15. A method as in claim 13, further comprising a second contact layer, formed over the plurality of quantum well elements.

16. A method as in claim 15, further comprising doping the contact layer with N type charge carriers.

17. A method as in claim 2, further comprising adjusting an angle of incidence of radiation that is input into said plurality of quantum well elements.

18. A method as in claim 17, wherein said adjusting comprises a forming a structure on top of said quantum well elements that changes an angle of incident radiation.

19. A method as in claim 18, wherein said adjusting comprises forming a structure including a polished facet at a specified angle on top of said quantum well elements.

20. A method as in claim 18, wherein said structure includes a randomly roughened reflecting surface.

21. A method as in claim 17, further comprising forming an electrical contact layer over said quantum well elements, and wherein said adjusting comprises forming a structure on said electrical contact layer.

22. A method as in claim 21, wherein said structure includes a randomly reflecting structure.

23. A method as in claim 22, wherein said randomly reflecting structure is formed of a highly reflective material.

24. A method as in claim 6, wherein said GaAs layers are between 40 and 70 angstroms thick, and said $Al_xGa_{1-x}As$ layers are between 500 and 600 angstroms thick.

25. A method as in claim 4, wherein said first material is between 40 and 70 angstroms thick, and said second material is between 500 and 600 angstroms thick.

26. A method as in claim 4, wherein said supporting comprises supporting an excited bound energy state that is within 2 percent of said well top.

27. A method as in claim 6, further comprising a second barrier layer, of a different material then said barrier layer, between adjacent barrier layers.

28. A method, comprising:

forming a plurality of quantum well elements, each quantum well element including a well portion of a first specified material, surrounded by first and second barrier layers formed

of at least one second specified material, each well layer including a well bottom and a well top, said forming comprising adjusting characteristics of said first and second specified materials, to support bound energy levels with an excited bound energy state that is close to being resonant with said well top; and

adjusting a direction of input radiation to said plurality of quantum well elements, to adjust an electric field polarization of said input radiation, relative to a quantum well growth axis.

29. A method as in claim 28, further comprising forming electrical contacts above and below said plurality of quantum well elements.

30. A method as in claim 28, wherein said adjusting comprises reflecting said input radiation at a specified angle relative to said growth axis.

31. A method as in claim 30, wherein said specified angle is 45 degrees.

32. A method as in claim 29, wherein said adjusting comprises forming a randomly roughened surface that produces light at a plurality of different angles relative to said growth axis.

33. A method as in claim 32, wherein said randomly roughened surface is formed on a structure over said plurality of quantum well elements.

34. A method as in claim 32, wherein said randomly roughened surface is formed on one of said electrical contacts.

35. A method as in claim 32, wherein said randomly roughened surface is formed of gold.

36. A method as in claim 28, further comprising forming a plurality of image sensor elements, and associating each of said image sensor elements with a plurality of said quantum well elements.

37. A method as in claim 36, wherein said forming comprises forming said plurality of image sensor elements into a two-dimensional array.

38. A method as in claim 37, wherein said forming a plurality of quantum well elements comprises forming a plurality of quantum well elements into a stack, and forming a plurality of electrical contact layers, and an element to adjust a direction of said input radiation, and wherein each of said quantum well stacks is associated with one of said plurality of image sensors.

39. A method as in claim 38 further comprising spatially aligning said quantum well stacks with said image sensors, and using an indium bump to attach said quantum well stacks to said image sensors.

40. A method as in claim 28, wherein said adjusting comprises adjusting said direction of input radiation using a technique which is substantially wavelength independent.

41. (Amended) A device, comprising:

a plurality of quantum well elements, each with a well layer having a well bottom, a well top, and bound energy states within said well, and first and second barrier layers surrounding said well layer, said well layers being formed of materials that cause a bound energy state to be [close to] <u>resonant with</u> said well top, at a level that allows an electron in said well to escape to an electron continuum area of higher energy state electrons, [by] <u>without</u> tunneling through material forming said barrier layers.

43. A device as in claim 41, further comprising an element that adjusts a direction of input radiation, relative to said quantum well elements.

44. A device as in claim 43, further comprising electrical contact layers, including a first electrical contact layer on a first side of said quantum well elements, and a second electrical contact layer on a second side of said quantum well elements.

45. A device as in claim 44, wherein said element that adjusts direction of input radiation is formed as part of one of said electrical contact layers.

46. A device as in claim 44, further comprising a plurality of image sensors, arranged in an array.

47. A device as in claim 46, wherein said plurality of quantum well elements are arranged into a plurality of quantum well stacks, each quantum well stack including a plurality of periods, each period comprising a well layer and first and second barrier layers, and each quantum well stacks associated with one of said image sensors.

48. A device as in claim 47, wherein each of said quantum well structures are spatially aligned with one of said image sensors.

49. A device as in claim 44, further comprising a plurality of bumps, connecting between said quantum well stacks and said image sensors.

50. A device as in claim 46, wherein said image sensors are CMOS image sensors.

51. A device as in claim 41, further comprising a plurality of image sensors, arranged in an array, and associated with said plurality of quantum well elements.

52. A device as in claim 51, wherein said plurality of quantum well elements are arranged into a plurality of quantum well stacks, and each said quantum well stack including a plurality of periods, and each of said periods comprising a well layer and first and second barrier layers, each of said quantum well stacks associated with one of said image sensors.

53. A device as in claim 52, wherein said quantum well stacks are respectively spatially aligned with said array of image sensors.

54. A device as in claim 48, wherein each of said image sensors has a peak sensitivity in the infrared region.

55. A device as in claim 54, wherein said well layer is formed of GaAs.

56. A semiconductor, comprising:

a plurality of semiconductor image sensors, arranged on a substrate in an array;

a plurality of quantum well stacks, respectively associated with said plurality of semiconductor image sensors, each said stack comprising a plurality of quantum well structures, each said quantum well structure having a barrier layer of a first semiconductor material, and a well layer of a second semiconductor material, said first and second semiconductor materials defining a band gap there between, each well layer of each quantum well structure coupled between two of said barrier layers, and each well layer having a well bottom and a well top, and each well supporting an unexcited energy state within said well, and a bound excited energy state for photo carriers, each of said well layers being selected such that the bound excited energy state is substantially resonant with a top portion of the well.

57. A semiconductor as in claim 56, wherein said semiconductor image sensors have peak sensitivity in the infrared range.

58. A semiconductor as in claim 56, further comprising a radiation direction adjusting element that adjusts a direction of input radiation relative to said quantum well stacks.

59. A semiconductor as in claim 58, wherein said radiation directing adjusting element includes a plurality of random reflectors.

60. A semiconductor as in claim 59, wherein said random reflectors are formed of gold.

61. A semiconductor as in claim 56, further comprising a plurality of electrical contacts, associated with said semiconductor.

62. A semiconductor as in claim 61, further comprising a plurality of random reflectors, operating to adjust a direction of input radiation.

63. A semiconductor as in claim 61, wherein said random reflectors are formed on one of said electrical contacts.

64. A semiconductor as in claim 56, wherein there are 50 of said quantum well structures in each of said quantum well stacks.

65. A semiconductor as in claim 57, wherein said well layers are formed of GaAs, and said barrier layers are formed of $Al_xGa_{1-x}As$.

66. A semiconductor as in claim 54, wherein said image sensors have a peak reception at 8.5 microns.

67. A semiconductor as in claim 56, wherein said quantum well is formed of $Al_yGa_{1-y}As$, and said barrier layer is formed of $Al_zGa_{1-z}As$.

68. A method, comprising:

forming a plurality of quantum well stacks on a substrate, each of said quantum well stacks including a plurality of quantum well elements, each quantum well elements having a barrier layer and a well layer, with each well layer being formed between two adjacent barrier layers, each well layer having a well bottom and a well top; and

treating an open surface of said substrate with a material that reduces a parasitic surface induced leakage in the quantum well stacks.

69. A method as in claim 68, wherein said material includes an inorganic sulfide.

70. A method as in claim 68, wherein said forming includes supporting bound energy levels within each said well layer, with an unexcited bound energy level being a level that is close to resonance with said well top.

71. (Amended) A semiconductor, comprising:

a plurality of semiconductor image sensors, arranged on a substrate in an array;

a plurality of quantum well stacks, respectively associated with said plurality of semiconductor image sensors, each said stack comprising a plurality of quantum well structures, each said quantum well structure having a barrier layer of a first semiconductor material that is greater than 300 microns in width, and a well layer of a second semiconductor material, said first and second semiconductor materials defining a band gap therebetween, each well layer of each quantum well structure coupled between two of said barrier layers, and each well layer having a well bottom and a well top, wherein each well supporting an unexcited energy state within said well, and a bound excited energy state for photo carriers, each of said well layers being selected such that the bound excited energy state is resonant with a top portion of the well.

72. A semiconductor as in claim 71, wherein said barrier layer is greater than 500 microns in width.

73. A semiconductor as in claim 71, wherein said semiconductor image sensors have a peak which is within the infrared range.

75. A semiconductor as in claim 74, wherein said semiconductor image sensors have a reception peak which is substantially at 8.5 microns.

76. A semiconductor as in claim 71, wherein said quantum well stacks each include at least 50 quantum well structures.

77. A semiconductor as in claim 71, wherein said semiconductor image sensors are image sensors.

78. A semiconductor as in claim 71, wherein each of said quantum well stacks is spatially aligned with each of said image sensors.

79. A semiconductor as in claim 71, further comprising a radiation direction adjusting element that adjust a direction of input radiation relative to said quantum well stacks.

80. A semiconductor as in claim 79, wherein said radiation adjusting element includes a plurality of random reflectors.

81. A semiconductor as in claim 80, wherein said random reflectors are formed of gold.

82. A semiconductor as in claim 80, wherein said random reflectors are formed of silver.

83. A semiconductor as in claim 71, wherein said quantum well structures are formed of GaAs, and said barrier layers are formed of $Al_xGa_{1-x}As$.

84. A method of forming a semiconductor, comprising:

obtaining a GaAs substrate;

first forming a barrier layer of at least 300 angstroms thick, of a barrier layer material, on said substrate;

second forming a well layer of a different material than said barrier layer material, on said barrier layer, said well layer being thinner than said barrier layer;

repeating said first forming and said second forming to form a desired number of quantum well structures; and

forming a radiation adjusting element over said quantum well structures, which adjust a characteristic of incoming radiation.

85. A method as in claim 84, wherein said forming a radiation adjusting element comprises forming a light changing element which includes a $\lambda/4$ phase shifting element.

86. A method as in claim 84, wherein said forming a radiation adjusting element comprises forming a plurality of random reflectors.

87. A method as in claim 84, further comprising an image sensor element, associated with said semiconductor.

88. A method as in claim 87, wherein there are plurality of said quantum well structures forming a plurality of stacks, and a plurality of image sensor elements, respectively associated with said stacks.

89. A method as in claim 88, further comprising an indium bump, coupling said quantum well structures to said image sensors.